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Surface Apparatus for Effecting Transfer of Heat Between Fluids

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3 Claims

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This invention relates to surface apparatus for effecting the transfer of heat between fluids, such apparatuses being commonly designated heat exchangers. Although heat exchangers according to this invention are intended more especially for the transfer of heat between gaseous fluids in flow, for example from gases of combustion to air under pressure for supporting combustion, the invention is not restricted to apparatus for dealing with gaseous fluids as heat exchangers embodying the invention may be employed for transferring heat from one liquid to another, or from a gaseous fluid to a liquid or vice versa.

In some of the various kinds of heat exchangers heretofore constructed or proposed, the two fluids flow in parallel paths through the exchanger, while in others the paths for one fluid are disposed transversely of the paths for the other fluid. In the former case, both fluids may flow in the same direction or in opposite directions, heat exchangers operating according to the contra-flow principle being found more efficient as regards the heat transfer effected.

Amongst the various forms of surface apparatus for the transfer of heat between fluids in flow are two well-known types which conveniently and usually are termed straight-tube type and plate type, respectively.

The present invention is concerned particularly with heat exchangers of the kind in which the respective fluids flow in parallel paths through the apparatus, the heat exchanger being of either the straight-tube or plate type.

It is the primary object of the present invention to provide an improved heat transfer unit for incorporation in a heat exchanger of the kind specified in the preceding paragraph which, in addition to being of simple construction, and such as can be readily built up into apparatus of the desired size or capacity and easily cleaned, or dismantled for cleaning or renewal, shall be such that the cross sectional area for the flow of the respective fluid through such unit shall be substantially constant and the paths for such fluid be free from abrupt changes of direction, thereby minimizing, or it may be eliminating, the pressure loss which obtains where a fluid is subject at certain stages in its flow to sudden expansion or contraction or has to negotiate sharp bends in its path.

Amongst other objects of the invention is the provision of headers for the supply and delivery of the respective fluids to and from the heat transfer units which shall be of simple construction and of a form permitting easy flow of fluid

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to or from the units without abrupt changes of direction liable to result in undesirable pressure drop in the fluids. It is also an object of the invention to provide an apparatus in which both fluids are supplied to and leave the exchanger through headers similar in shape and capable of being nested together in pairs.

Another object of the invention is to provide an improved tubular heat exchanger in which the construction of the heat transfer units and the headers shall be such as to avoid the employment of the tube plates usual where the tubes of the apparatus are so arranged that the paths for the respective fluids are parallelly disposed, the absence of tube plates not only permitting close pitching of the tubes comprised in the units but minimising leakage, and eliminating corrosion at the joints of the tubes with such tube plates, as well as effecting a reduction in weight and rendering the full tube length available for heat transfer.

Further, the invention seeks to provide improved heat transfer units for incorporation in heat exchangers such that the parallel flow paths through a unit may have approximately equal hydro-dynamic resistance thus ensuring substantially even distribution of fluid across the exchanger, and in which due to the parallel disposition of the fluid paths and the substantially even distribution of the fluids across the exchanger, the temperature of each fluid will be approximately uniform across the exchanger at any cross section thereof and the longitudinal expansion of all units will be substantially the same as also will be that of the constituent tubes or equivalent portions of each unit thus rendering unnecessary the provision of expansion joints for or in the units.

It is also an object of the invention to provide a heat exchanger in which, where laminar flow of the fluid through the heat transfer units is required it is possible to utilise economically large numbers of short lengths of small diameter tubing in the construction of tubular heat transfer units.

A still further object of the invention is to provide heat transfer units capable of arrangement in stacks which in turn can be disposed side by side without their obtaining between the stacks lanes through which the respective fluid might pass with comparatively little heat transfer.

According to this invention a heat transfer unit comprises means bounding a plurality of parallelly disposed paths for the flow of the internal fluid through the unit and over the surface of which

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means the external fluid flows, said paths having their inlet ends disposed side by side in a common plane and their outlet ends similarly disposed in a common plane, a junction portion common to all the paths of the unit and connected to the inlet ends of the said paths, said junction portion being of substantially constant cross-sectional area for fluid flow through it and affording a passage for fluid flow free from abrupt change of direction while permitting, when a number of units are assembled in the exchanger, free passage of the external fluid between the junction portions thereof for flow over the outer surface of the units, without abrupt change of direction of flow, and a similar junction portion common to all the paths of the unit and connected to the outer ends of said paths, the junction portions, the cross sectional area for fluid flow through each of which is equal or approximately equal to the sum of the cross sectional areas of the fluid paths of the unit and which are of less depth at their ends connected to the fluid paths than the overall depth of said paths, being adapted to be connected in turn to inlet and outlet headers, respectively, for the internal fluid.

The expression "common plane" used herein is intended to include not only a plane proper but also a surface of revolution.

A heat exchanger embodying the invention comprises a number of heat transfer units arranged in a stack or stacks in a casing, the said stack or each stack being equipped with, or connected to, inlet and outlet headers for the internal fluid.

The fluid which flows over the outer surface of the units may be supplied thereto and flow therefrom through headers which may be similar, or even identical, in form with those for the fluid flowing through the units and be so constructed that a header for one fluid may be nested with a header for the other fluid to form a pair.

Each junction portion of a heat transfer unit according to the invention, which may be of rectangular cross section throughout its length, tapers in width between its end connected to or communicating with the fluid paths of the unit and its other and deeper end connected to the respective header and tapers in depth between the latter end and the former and wider end, the fluid paths being fashioned at the ends of said paths to bound areas each of the same shape and dimensions as that bounded by the wider and shallower end of the respective junction portion of the unit. Each junction portion of a unit may be so shaped that at each of its narrower sides it provides two surfaces diverging from a sharp meeting edge and blending into the wider sides of the junction portion, these diverging surfaces deflecting the fluid which flows over the unit and enabling it to reach the heat transfer surface of the unit without abrupt change of direction of flow.

In the accompanying drawings:

Fig. 1 illustrates a heat exchanger comprising tubular heat transfer units according to one embodiment of the invention.

Fig. 2 shows in plan and Fig. 3 in elevation one of the tubular heat transfer units comprised in the heat exchanger illustrated in Fig. 1.

Fig. 4 is an end view of a stack of three of the heat transfer units shown in Figs. 2 and 3.

Figs. 5 and 6 are fragmentary views illustrating a constructional detail of a tubular heat transfer unit comprising two rows of tubes, Fig. 5 being a view of the end of the unit as seen

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from the right hand side of Fig. 6 and Fig. 6 a sectional view of a portion of the unit partly on the line A-B and partly on the line C-D of Fig. 5.

Figs. 7 and 8 show, more or less diagrammatically, heat exchangers with tubular heat transfer units according to other embodiments of the invention.

Fig. 9 shows in plan a plate type heat transfer unit according to an embodiment of the invention, with a portion of another unit which would lie adjacent to it in the heat exchanger.

Fig. 10 is a side view of two units according to Fig. 9 as they appear when superposed.

Fig. 11 illustrates units as shown in Figs. 9 and 10 in end view.

Fig. 12 shows a modified form of junction portion for heat transfer units embodying the invention.

Figs. 13 and 14 are fragmentary views illustrating one form of header which may be employed in heat exchangers comprising heat transfer units according to the invention, Fig. 13 being a section on the line E-F, Fig. 14, the latter figure being a plan.

Fig. 15 is a fragmentary view showing in end elevation an assembly of heat transfer units according to an embodiment of the invention in an annular heat exchange apparatus.

Fig. 16 illustrates a modified arrangement of units assembled in a cylindrical casing.

Fig. 17 shows a header unit according to the invention, and

Fig. 18 illustrates a pair of the header units according to Fig. 17 nested together, with one of the units connected to the junction portions of a stack of heat transfer units according to an embodiment of the invention.

Referring first to Fig. 1 of the drawings, 1 is the casing of a heat exchanger, the heat transfer surface of which is provided by an assembly of heat transfer units according to an embodiment of the invention. The casing shown is built up of plates which may be assumed to be detachably secured together by any convenient means (not shown) and at its ends is open for the flow through it of the external fluid. Within the casing are nine heat transfer units of the construction shown in Figs. 2, 3 and 4, arranged in three stacks each comprising three units. Each stack is connected at one end to an inlet header 2 and at the other end to an outlet header 3 for the internal fluid, the headers and the ends of the casing being connected with the appropriate ducting. Preferably the units in a stack are detachably connected to one another and to the headers to enable the parts to be disassembled for inspection, cleaning or renewal.

Referring now to Figs. 2, 3 and 4, in constructing the tubular unit therein illustrated the end portions 4 of the component tubes 5 are brought to oblong rectangular shape in cross section and the tubes are arranged in a common plane with the shorter sides of the rectangular end portions of adjacent tubes in contact, these sides being then welded or brazed together. As shown, the rectangular portions 4, which are of a depth less than the diameter of the tubes, are of a width greater than said diameter so that except at their rectangular ends said tubes are spaced apart.

The extreme ends of the rectangular portions 4 of the tubes are connected by welding or brazing to the junction portions 6, which as shown are of rectangular cross section throughout their length, each tapering in width from its end 7

connected to the portions 4 of the tubes towards its other or open end 8 which is connected to the respective header, and tapers in depth from the end 8 towards the end 7.

At its end 7 communicating with the fluid paths in the unit, the junction portion 6 extends the full width of the unit but is of a depth less than the diameters of the tubes 5 constituting the unit, while at its end 8 for connection to the header it is of less width, for example one half or approximately one half said width, than the fluid path portion of the unit, and of a depth greater than the diameter of the tubes, the cross sectional area of such junction portion remaining constant throughout its length and being equal or approximately equal to the sum of the cross sectional areas of the fluid paths of the unit. As will be appreciated from Fig. 4, the junction portions are such that when units are superposed the tubes in one unit are spaced from those in the next unit.

The constituent tubes 5 of a tubular unit may be arranged to lie in two parallel planes for the major portion of their length, with the tubes in one plane in staggered relation to those in the other plane as illustrated by Figs. 5 and 6, the end portions 4 of the tubes being brought into an intermediate common plane and into rectangular shape in cross section for connection to one another and to the junction portions of the unit. In the construction shown the tubes are spaced at less than a diameter apart, and in consequence the longer sides of adjacent rectangular end portions 4 are in contact.

It will be convenient now to describe the heat transfer units illustrated in Figs. 9, 10 and 11. These units are of the plate type and each is constructed of a pair of identical plates 9 each corrugated for the major portion of its length, the extreme end portions 10 of the plates being left plane for connection to, or for formation into, the junction portions 6 of the unit, while the longitudinal edges 11 are bent at right angles to the general plane of the plate. When assembling two plates 9 to form a unit, one plate is reversed so that the crests of its corrugations at the respective side register with and contact the corresponding crests of the corrugations of the other plate. The plates are then welded at their longitudinal edges 11, and if desired at the abutting crests. In the latter event, the crests may be seam welded together or spot welded at intervals. At the ends of the fluid path portion of the unit, the portions 10 of the plates which are left plane or free from corrugations are so formed that when the plates are united such plane portions bound a rectangular space which adjacent the fluid paths is of the full width of the unit and of approximately one half the overall depth of the unit as will be seen by reference to Fig. 11.

The manner in which the plates are corrugated may be varied as desired. Thus, instead of the corrugations being more or less V-shape in cross section they may be of the more usual arcuate shape, or, where a large cross sectional area for flow of the external fluid is required, semi-circular section corrugations may be pressed in each plate from one side thereof with flat portions or lands between them. In the latter event two plates, one having been reversed, are secured together with their flat portions in contact, thus forming a number of circular fluid paths with the walls of adjacent paths joined by fin-like portions.

In the embodiment of the invention already described the junction portions 6 of the units are of rectangular cross section throughout, but conveniently each junction portion of a unit may be shaped as shown in Fig. 12 so that at each of its narrower sides it provides upper and lower surfaces 12 diverging from a sharp meeting edge 13 and blending into the wider sides of the junction portion, these diverging surfaces deflecting the fluid which flows over the unit and enabling it to reach the heat transfer surface of the unit without abrupt change of direction of flow.

A stack of heat transfer units according to this invention may have headers of sectional construction, as shown in Figs. 13 and 14, the sections 14 being integral with the junction portions 6 of the units, or joined thereto. These header sections 14 are more or less in the form of flanged rings or short cylinders adapted to be superposed and secured together by bolts 15 passing through lugs 16 on the sections, the end of a junction portion 6 of a unit blending into the peripheral wall of the respective ring or being welded thereto, and such portion communicating with the bore of the ring through an aperture 17 in the said wall thereof. 18, Fig. 14, is a cover plate closing a cleaning opening in the header section wall.

Heat exchangers according to this invention may be built up in various forms; thus they may be such that the headers for the fluid flowing through the heat transfer units are disposed at opposite ends of the exchanger as shown in Fig. 1, or the inlet and outlet headers for such fluid may be at the same end as shown in Figs. 7 and 8. In the latter case each heat transfer unit comprises flow and return portions 19, 20, respectively, lying in a common plane and each having a plurality of paths for fluid flow, the flow and return portions being disposed on opposite sides of a partition or baffle 21 in the casing 22. The fluid flow paths of the flow and return portions of the unit, which may be of the tube type shown or of the plate type, may be connected by arcuate path portions 23, Fig. 7, extending around the end of the baffle 21 so that continuous U-shape paths are formed, or the paths of the flow and return portions may terminate, as shown in Fig. 8, in junction portions 6 connected by a single U-shaped duct 24, in which case the said duct may include a detachable connection. Conveniently and as shown it may be divided intermediate its ends and the portions be detachably secured together, for example by the flanges 25 and bolts (not shown). In such a heat exchanger the headers may be of the hereinbefore described sectional form shown in Figs. 13 and 14, or of any other convenient form and the casing may be provided with removable end covers or other removable portions enabling ready access to be obtained to the units for inspection, cleaning or renewal.

Where the heat exchanger according to the invention is for use with high pressure fluids, the casing may be cylindrical and the units be assembled into stacks which are sector shaped in cross section, as shown in Figs. 15 and 16, the header connections being made through the peripheral wall of the casing 26 or through its ends. As the units would be of progressively increasing width from the centre of the casing outwards, the headers conveniently may be of tapering form and may be unitary or sectional. It will be appreciated that the central region of the casing around its longitudinal axis cannot conveniently be occupied by heat transfer surface, and this region may be enclosed by a tube or inner cylindrical casing 27 which may accommodate the

shaft of a gas turbine or other rotary apparatus, e.g. an air compressor. The units may be flat or of arcuate cross section. In the case of arcuate section units shown in Fig. 15, such units may extend around any desired arc of the casing, e.g. one quarter as shown, or may even be cylindrical, in which latter event each unit would comprise a plurality of appropriately spaced junction portions for connection to the requisite number of headers. Tubular units are shown in the drawings and the ends **28** of the tubes are brought to a more or less trapezoidal shape in cross section. Where units are flat, as shown in Fig. 16, appropriately shaped plates **29** may be arranged to close those spaces between the outer units and the peripheral wall of the casing **26** which cannot be economically filled with tubes and which otherwise would constitute lanes through which fluid would flow freely with little transfer of heat.

Referring now to Figs. 17 and 18, as already mentioned the several headers of a heat exchanger, according to one embodiment of the invention, may be similar, or even identical in form. As shown in these figures, they are identical in form, and each comprises a vertical portion **30** of a height equal to the height of the stack of heat transfer units to which it appertains, and of a width equal to that of the outer ends of the superposed junction portions **6** of the units forming the stack, and a transverse portion **31** in open communication with and of approximately one half the height and twice the width of the vertical portion. The vertical portion **30** of the header is open at its face opposing the units while the transverse portion which is disposed at the reverse face of the header is open at its face remote from the said vertical portion. One side **32** of the latter and one end **33** of the transverse portion **31** lie in a common plane, and one end **34** of the vertical portion and the upper or lower side **35** of the transverse portion lie in another common plane at right angles to the first mentioned common plane. When nested together, as shown in Fig. 18, the vertical portions **30** of the headers of a pair lie side by side, one registering with the open ends of the junction portions of the stack of units, and the other with the space between said ends and the corresponding ends of the junction boxes of an adjacent stack of units, while the transverse portions **31** of the headers lie one above the other. The contacting walls **36** of the two headers are curved and appropriately shaped as shown to fit snugly together while at the same time presenting smooth surfaces, free from angles, to the fluids flowing through the headers which are of constant cross sectional area throughout.

Where one header of a pair is required to pass a greater quantity of fluid than the other, one header while being of similar shape to the other and capable of nesting therewith, may be of greater cross sectional area than the other.

The vertical portion **30** of one header of each pair is connected to the respective ends of the units of the stack to which it appertains and supplies fluid to or receives it from said units while the vertical portion of the other header of each pair, which is in open communication with the space between the ends of the units in adjacent stacks, or between a stack of said ends and the casing, supplies or receives the fluid flowing over the units. The transverse portions **31** of the headers are connected to the ducting for the respective fluids flowing through the heat exchanger.

Any convenient means may be employed for attaching the junction portions of the units to the headers for the fluid flowing through the units. Where it is desired to form a stack of units and the appropriate headers into a unitary structure, the junction portions of the units may be welded or brazed to each other at their open ends and the said ends welded to the headers. Should it be desired that the units be individually removable the junction portions may be flanged or otherwise appropriately formed at their open ends and be bolted to the headers.

A heat exchanger according to this invention may have its constituent units constructed to provide passages or paths for fluid flow through them of any desired cross sectional area, and in either the tubular or plate type units said passages may be of a cross sectional area sufficiently small to ensure laminar flow of the fluid passing through them thereby obtaining a larger heat transfer for a given pressure drop than would be the case should turbulent flow of such fluid obtain. In addition, to obtain the greatest mean temperature difference and hence the most efficient heat transfer for a given pressure drop, the heat exchangers according to this invention are preferably arranged to operate on the counter flow principle. Further, the whole of the surface of the junction portions of the units is available for heat transfer, and where the counter flow principle is adopted the same mean temperature difference will obtain at said portions as in the main heat transfer surface portions of the units.

In the embodiment of the invention shown in Figs. 9, 10 and 11 the corrugated plates **9** of which a unit is formed have their end portions **10** plane and shaped as requisite to constitute the junction portions **6** of the unit. The invention is not restricted in this respect, as if desired the plates may be corrugated throughout their length, and the junction portions **6** be formed separately therefrom and be welded thereto, in which case the appropriate walls of the junction portions would be corrugated at their ends opposing the plates to conform to and match with the corrugations in the respective plates.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A heat transfer unit, for exchanging heat between internal and external fluids flowing in parallel directions respectively through and over a plurality of such units arranged in a stack comprising a main heat transfer portion having paths through which the internal fluid flows, said paths, including their inlet and outlet ends, being disposed parallelly in a common plane with the said inlet ends in open communication with an open-ended inflow junction portion and the said outlet ends in open communication with an open-ended outflow junction portion, each of such junction portions, which has walls fashioned to bound a space tapering in width in the direction away from the aforesaid paths and in depth in the direction towards said paths, having the cross sectional area for fluid flow through it constant throughout its length and approximately equal to the combined cross sectional area of the fluid paths with which it communicates, and being at its end nearer said paths of less depth than the overall depth of the paths while at its end remote from said paths it has a formation the depth of which is at least as

great as the overall depth of said paths and the width of which is less than the overall width of said paths, the formation of the junction portions providing for the contiguous edges of all the junction portions at an end of a stack of units to be joined fluid-tightly to each other and the stacked and joined junction portions to register with, and be connected directly to, a single opening in a header at said end of the stack without imposing on the internal fluid any abrupt change in direction while at the same time permitting free flow of the external fluid in a direction parallel with the direction of flow of the internal fluid through spaces at each side of the stacked junction portions of the units and within the overall width of the units.

2. A heat transfer unit as claimed in Claim 1 having its internal fluid paths formed by two corrugated plates disposed one above the other with the bases of the corrugations of the upper plate registering with and contacting the crests of the lower plate, said plates having their longitudinal edges and the abutting bases and crests of the corrugations welded together, and having at each end of the unit a junction portion which at its

shallowest part is of the full width of the unit and of approximately one-half its overall depth.

3. A heat transfer unit as claimed in Claim 1 having its internal fluid paths formed by two corrugated plates disposed one above the other with the bases of the corrugations of the upper plate registering with and contacting the crests of the lower plate, said plates having their longitudinal edges and the abutting bases and crests of the corrugations welded together, and having at each end of the unit a junction portion which at its shallowest part is of the full width of the unit and of approximately one-half its overall depth, the corrugations in the plates extending the full length of said plates, and the walls of the junction portions being corrugated at their ends which oppose the plates to match and register with the corrugations in the latter and such corrugated walls of the junction portions being welded to the plates.

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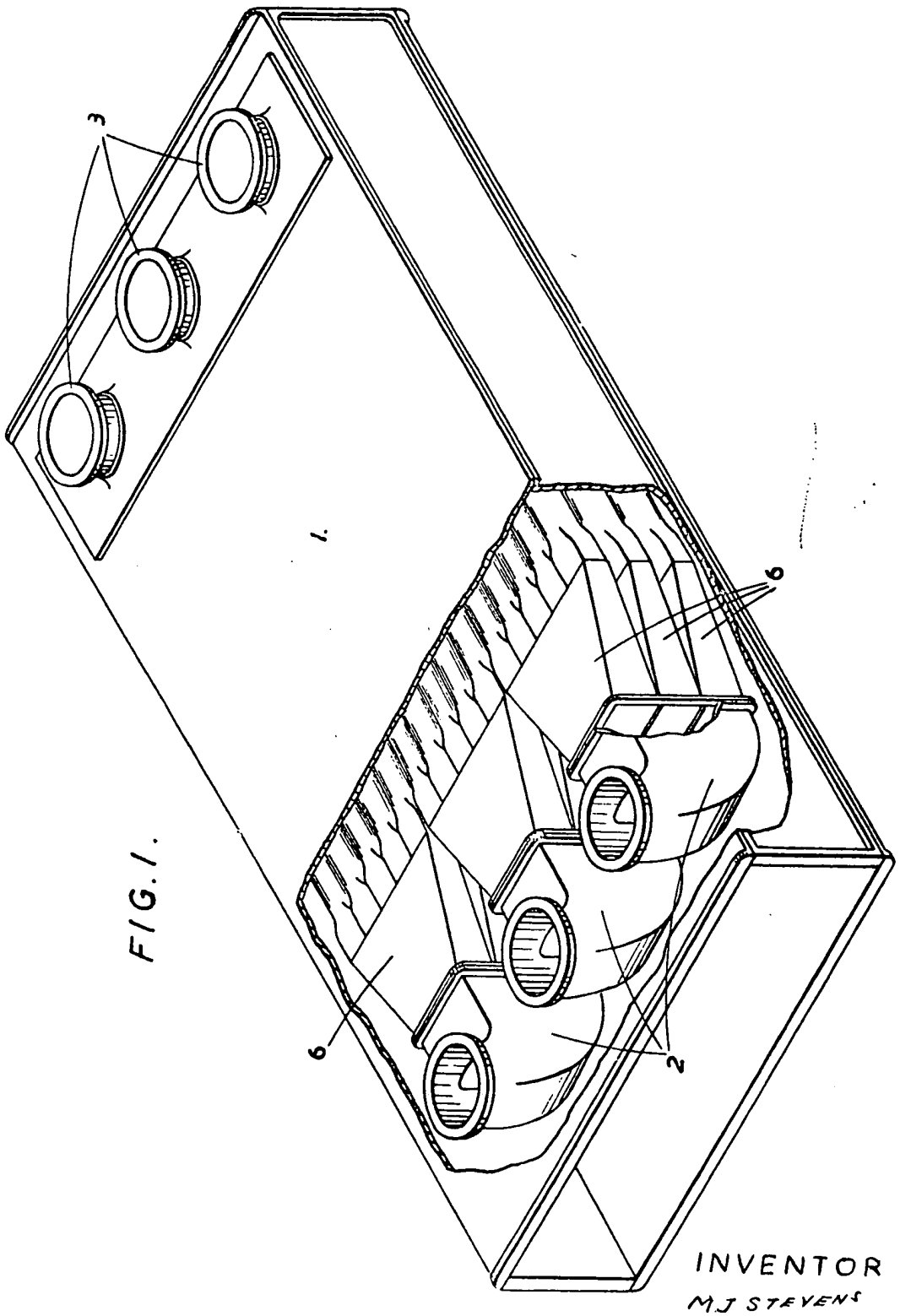

FIG. 1.

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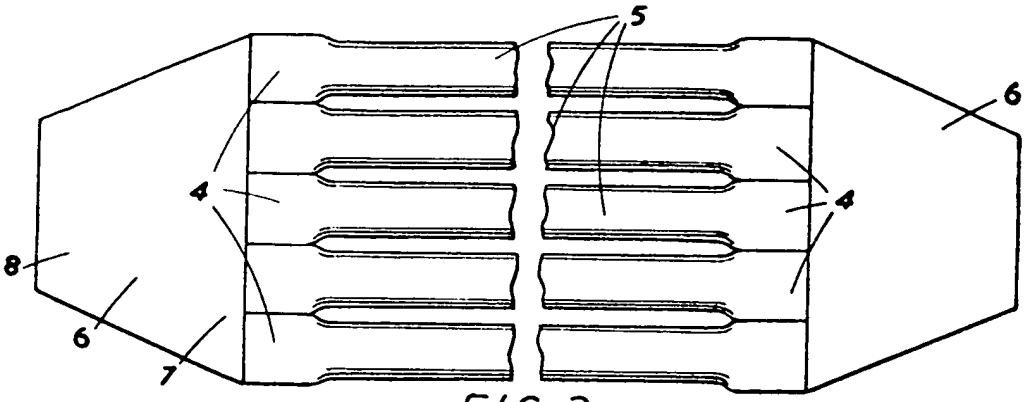


FIG.2.

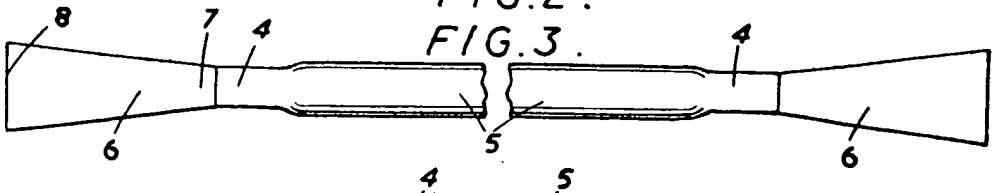


FIG.3.

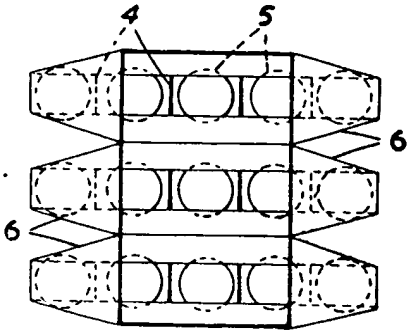


FIG.4.

FIG.5.

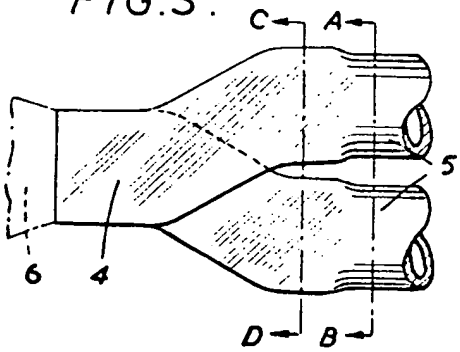


FIG.6.

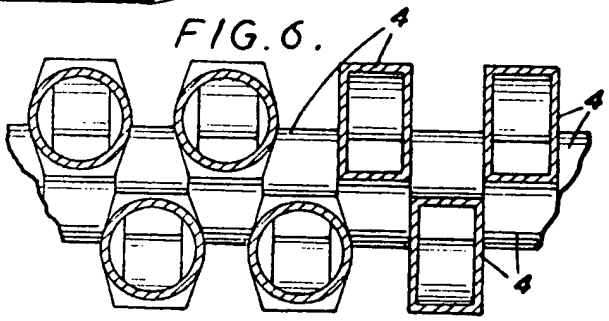
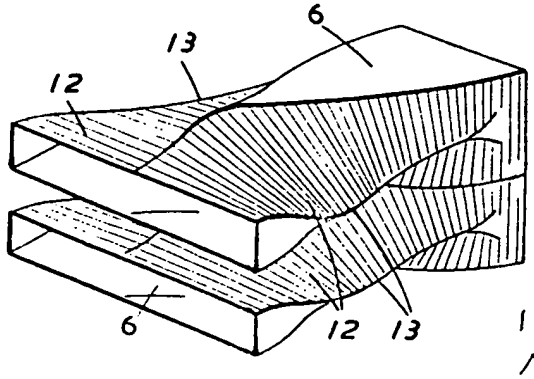


FIG.12.



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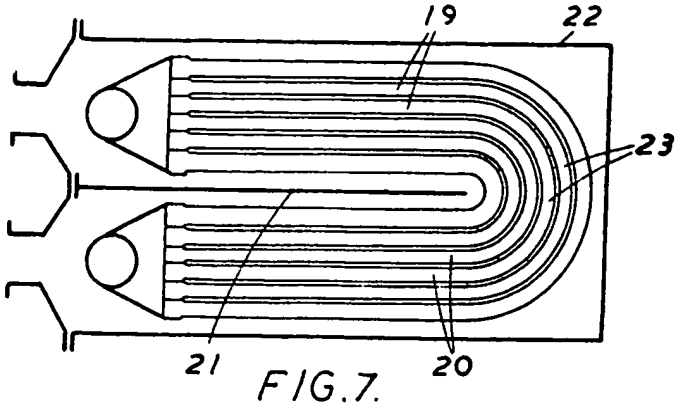

FIG.7.

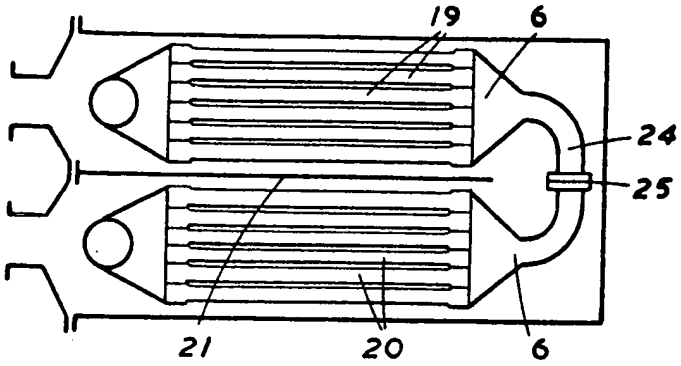

FIG.8.

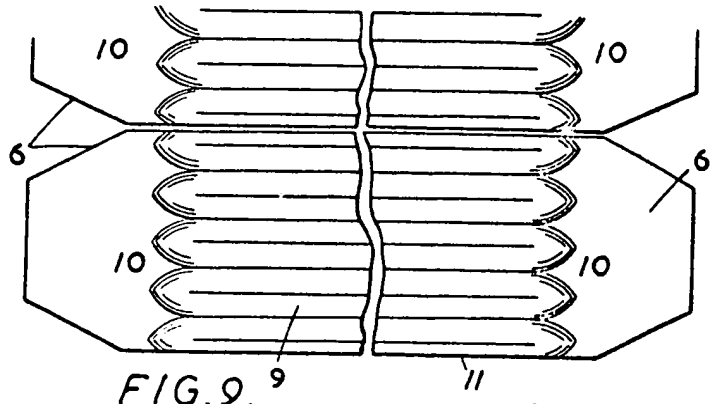

FIG.9.

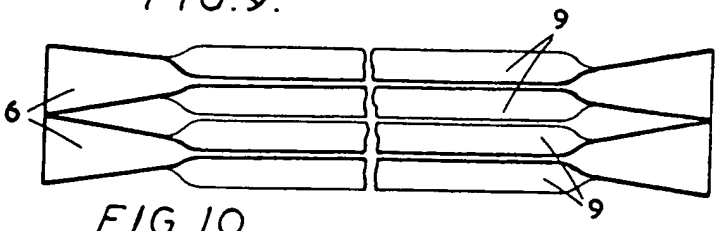

FIG.10.

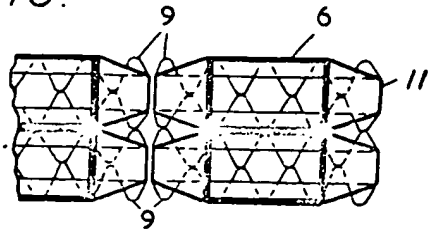

FIG.11.

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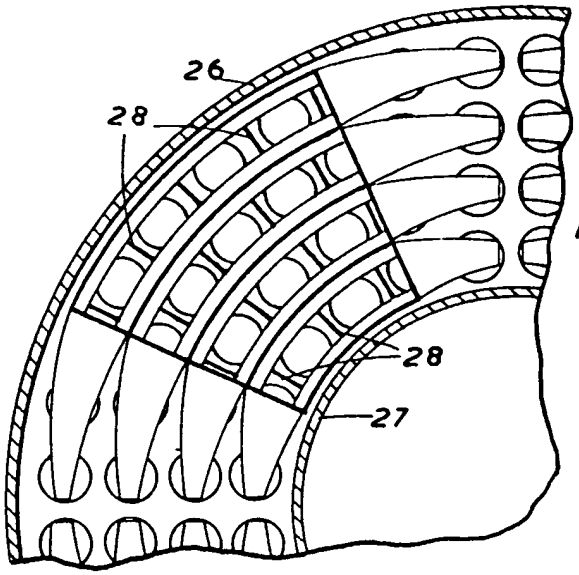


FIG.15.

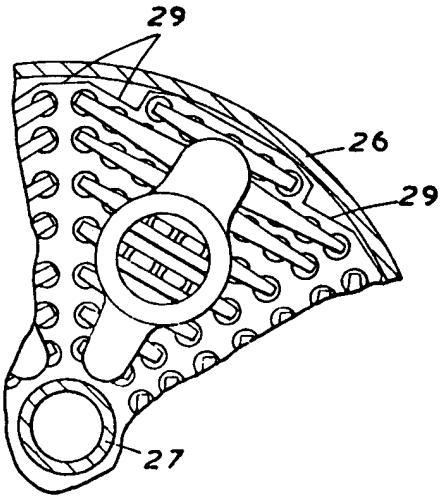


FIG.16.

FIG.14.

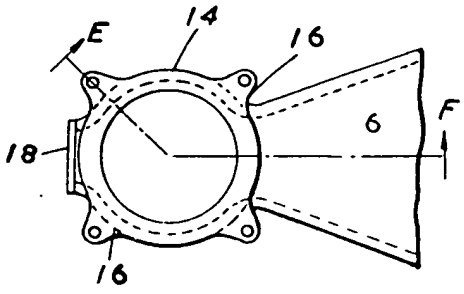
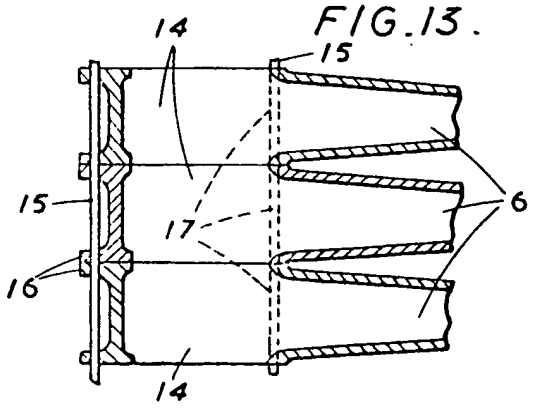


FIG.13.



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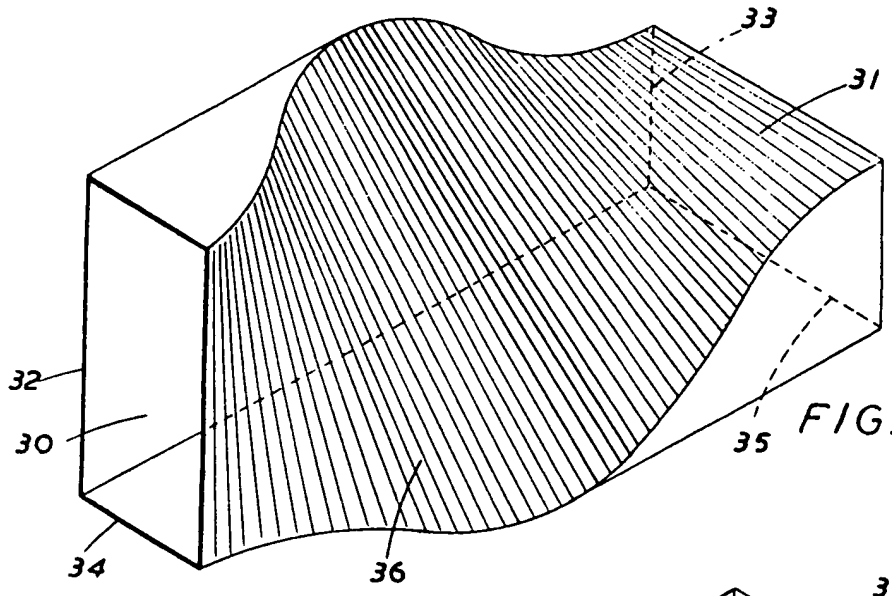
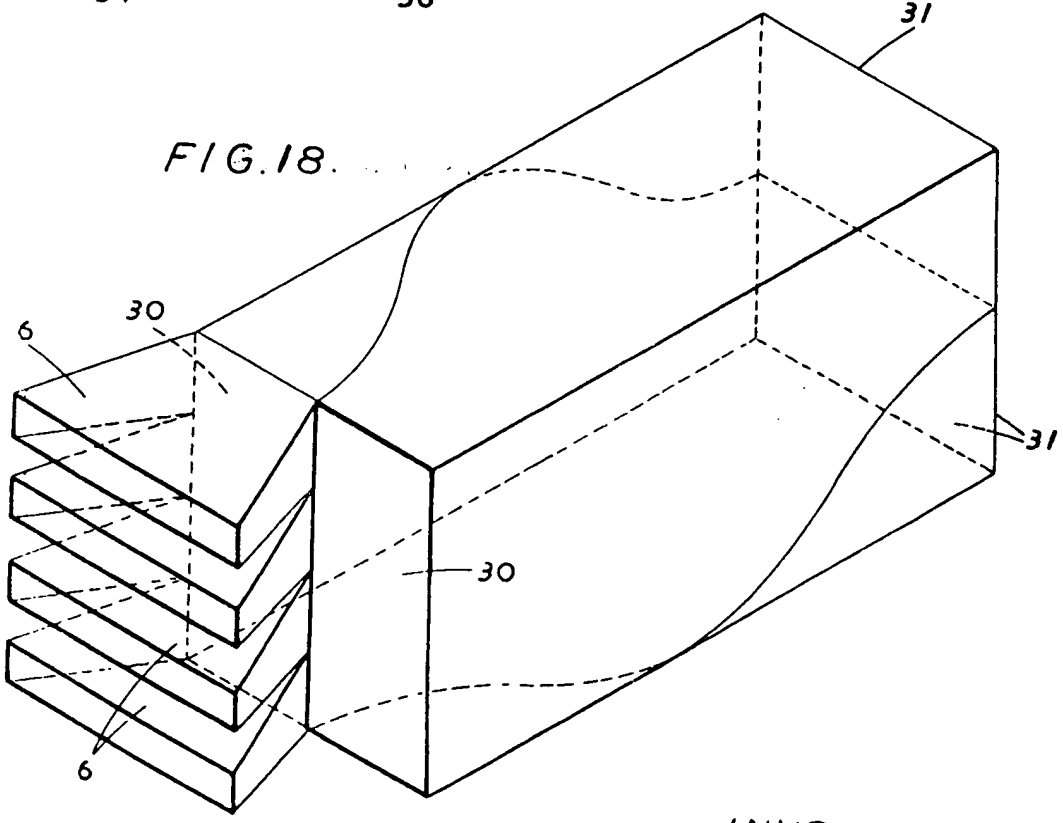


FIG. 17.

FIG. 18.



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